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Investigations of a new eclipsing cataclysmic variable HBHA 4705-03

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Abstract. Results of photometric and spectroscopic investigations of the recently discovered eclipsing cataclysmic variable star HBHA 4705-03 are presented. The emission spectra of the system show broad hydrogen and helium emission lines. The bright spots with an approximately zero velocity components are found in the Doppler maps for the hydrogen and ionized helium lines. The disc structure is more prominent in the maps for the neutral helium lines. The masses of the components ($M_{WD} = 0.54 \pm 0.10 M_{\odot}$ and $M_{RD} = 0.45 \pm 0.05 M_{\odot}$), and the orbit inclination ($i = 71.^\circ 8 \pm 0.^\circ 7$) were estimated using the radial velocity light curve and the eclipse width. The modeling of the light curve allows us to evaluate the bright spot parameters and the mass accretion rate ($\dot{M} \approx 2 \cdot 10^{17} \text{ g s}^{-1}$).

1. Introduction and Observations

For the first time HBHA 4705-03 ($\alpha_{2000} = 22^h 16^m 50^s.8$, $\delta_{2000} = +46^\circ 46.6'$) was found as an object with H_{α} emission line (Kohoutek & Wehmeyer 1997), and recently identified as an eclipsing cataclysmic variable (CV) (Korotkiy & Kryachko 2006) with the orbital period $0.^d 1718(1)$.

The photometric observations of this close binary were performed on August, 15-16 and 26-27, 2006 (V band) and on August, 16-17, 2006 (B band), with the 1-meter telescope Zeiss1000 at the Special Astrophysical Observatory (Russia) with an exposure time of 120 sec. The total observation time was about 11 hours and the observations were calibrated against SDSS standard stars. The example of the obtained light curves is shown in Fig.4. These observations give the ephemeris of the system eclipse ($\text{HJD} = 2453974.491(2) + 0.^d 171814(27) \times E$). Spectroscopic observations of HBHA 4705-03 were carried out on August, 30-31, 2006 and July, 21-22, 2007, by the 6-meter telescope BTA of the Special Astrophysical Observatory with the SCORPIO focal reducer (Afanasiev & Moiseev 2005), which gives a $\Delta\lambda = 5.0 \text{ \AA}$ resolution in the wavelength region $\Delta\lambda 3900\text{--}5700 \text{ \AA}$. 16 subsequent spectra with the same exposure time of 300 s and the signal-to noise ratio $S/N \approx 55 - 65$ were obtained. Examples of the obtained spectra are shown in Fig.1. The orbital phases are counted from the photometric minimum.

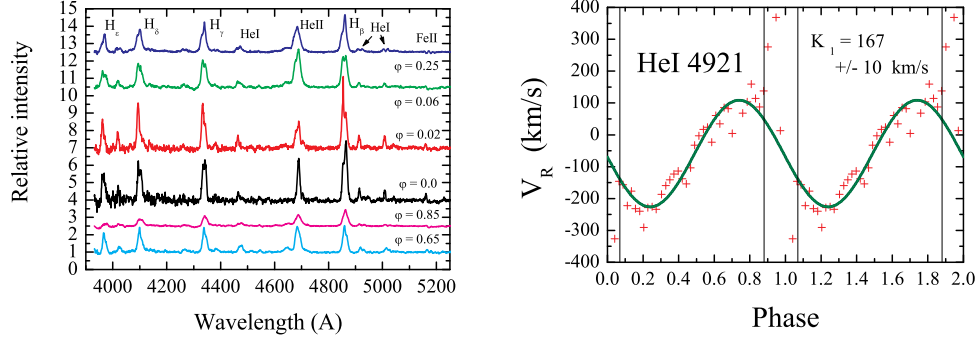


Figure 1. *Left:* Normalized observed spectra in six orbital phases. *Right:* Dependence of the radial velocity on the orbital phase, obtained using HeI 4921 emission line (21.07.07). The sine which fits the radial velocity curve in 0.1 – 0.9 phase range are shown by the solid curve.

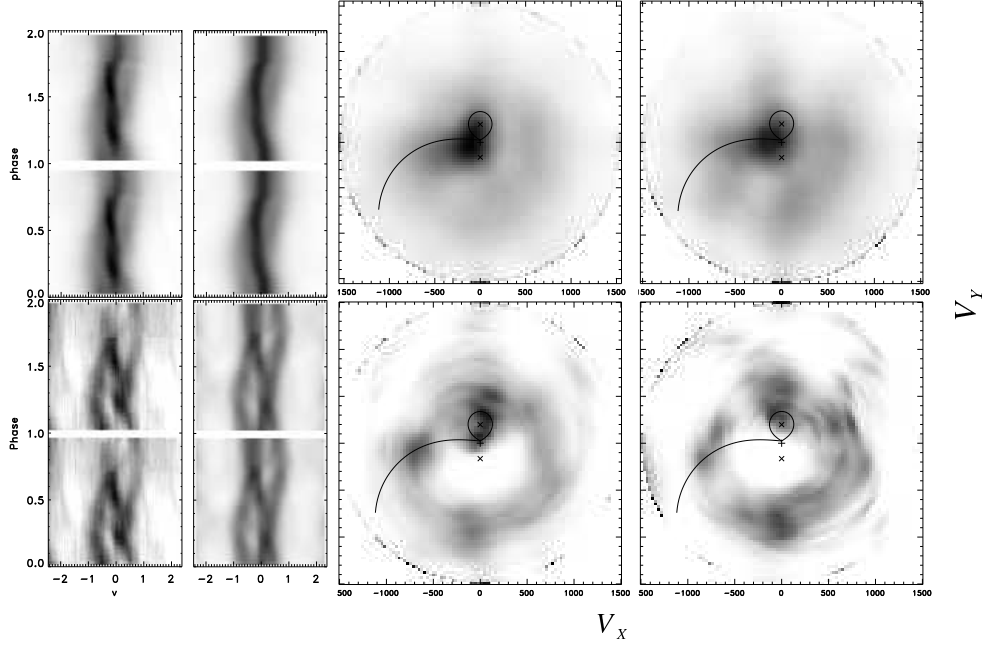


Figure 2. Two left columns of the panels: trailed spectra of H_β (top panels) and HeI 4921 (bottom panels), observed (left panels) and restored from the Doppler maps (right panels). Velocities in the X-axes are in 1000 km s^{-1} . Two left columns of the panels: Doppler maps for the same lines for two nights (30.08.06 and 21.07.07).

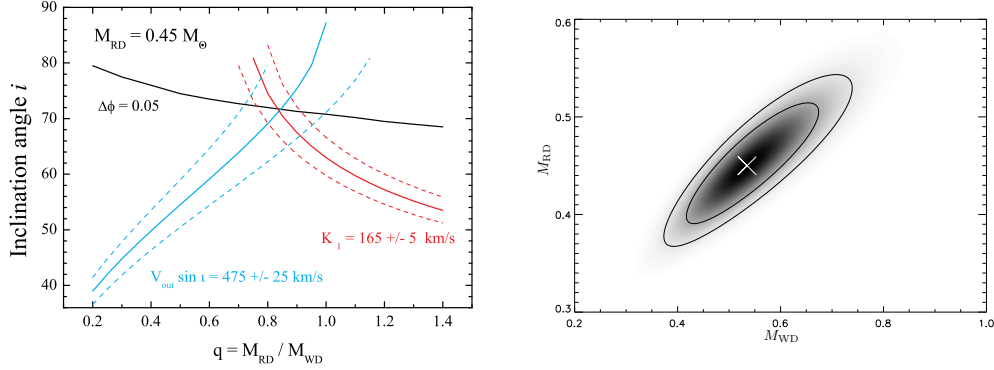


Figure 3. *Left:* The relationships between the mass ratio q and the inclination angle i calculated for $M_{\text{RD}} = 0.45 M_{\odot}$ and for the fixed values of the observed parameters. *Right:* Distribution of the total probability that the observed data correspond to given $M_{\text{WD}} - M_{\text{RD}}$ pair. 1- and 3- sigma contours are also shown.

2. Data Analysis

The most prominent details in the observed spectra of HBHA 4705-03 are the broad single peaked emission lines of hydrogen as well as neutral and ionized helium (Fig. 1, left panel). The line profiles are strongly changing with the orbital phase, especially at the moment of the eclipse, when they become double-peaked.

The radial velocity of the white dwarf was measured using the emission hydrogen lines by Shafter's method (Shafter 1983). Dependence of the radial velocity on the orbital phase for HeI 4921 is shown in Fig. 1 (right panel). The radial velocity curves were fitted by sine in the phase range 0.1 – 0.9.

Doppler maps of the system for seven spectral emission lines were created using Spruit's code (Spruit 1998). The trailed spectrogram for H_{β} and corresponding Doppler map, and the same for HeI 4921 are shown in Fig. 2. It is clear from the Doppler maps that there is a bright spot at L_1 and an extended disc structure.

3. Estimation of system parameters

The eclipse width ($\Delta\phi \approx 0.05$) provides us the relation between the inclination angle i and the mass ratio $q = M_{\text{RD}}/M_{\text{WD}}$ (Horne 1985).

The amplitude of the radial velocity $K_1 = 165 \pm 5 \text{ km s}^{-1}$ and the Kepler velocity at the outer disc radius $V_{\text{out}} \sin i = 475 \pm 25 \text{ km s}^{-1}$ determined from the half of the distance between emission line peaks (see details in Yakin et al. 2010, 2011) give two additional relations between M_{RD} , i and q . We take both values from the measurement of HeI lines because Balmer and HeII lines are distorted by the strong component which arises at the inner Lagrange point. Using this information we calculated the allowed regions in the i - q and $M_{\text{WD}} - M_{\text{RD}}$ planes shown in Fig. 3. Finally, we have $M_{\text{WD}} = 0.54 \pm 0.1 M_{\odot}$, $M_{\text{RD}} = 0.45 \pm 0.05 M_{\odot}$, and $i = 71.^\circ 8 \pm 0.^\circ 7$.

We modeled the observed light curve using Stupalov's code (see details in Yakin et al. 2011) with the fixed system parameters mentioned above. As a result we estimated the

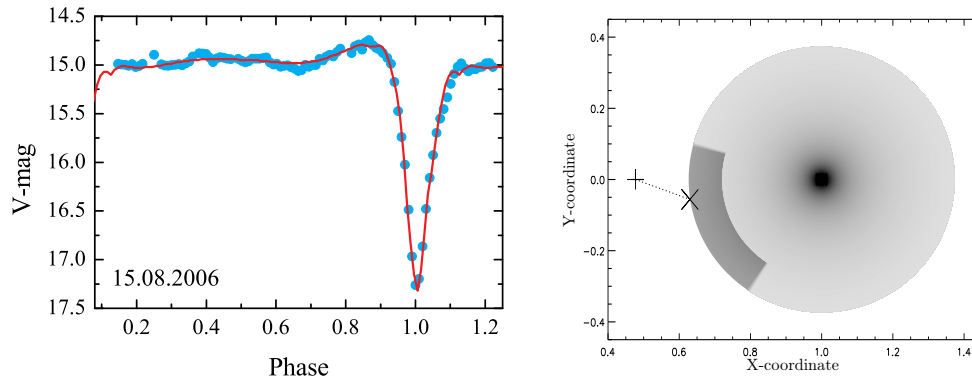


Figure 4. *Left:* The observed light curve together with the best model fit. *Right:* The model of an accretion disk with the bright spot. The red dwarf is on the left, at $X < 0.4$. The brightness of the disk regions corresponds to the temperature. The accretion stream trajectory is shown by the dashed line.

bright spot geometry and the temperature (≈ 16000 K) together with the mass accretion rate $\dot{M} \approx 2 \cdot 10^{17} \text{ g s}^{-1}$. The results are shown in Fig.4. The mass accretion rate and the mass of the secondary are in a good agreement with the expected values estimated from the empirical relation $M_{\text{RD}} - P_{\text{orb}}$ (Knigge 2006) and the theoretical calculations (Howell et al. 2001).

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